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Constraining microphysical assumptions in GPM algorithms using GPM-GV observations

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Funding: NASA PMM Science Team, NASA GPM Project, NASA ESS Fellowship

THE DEPARTMENT OF ATMOSPHERIC SCIENCES

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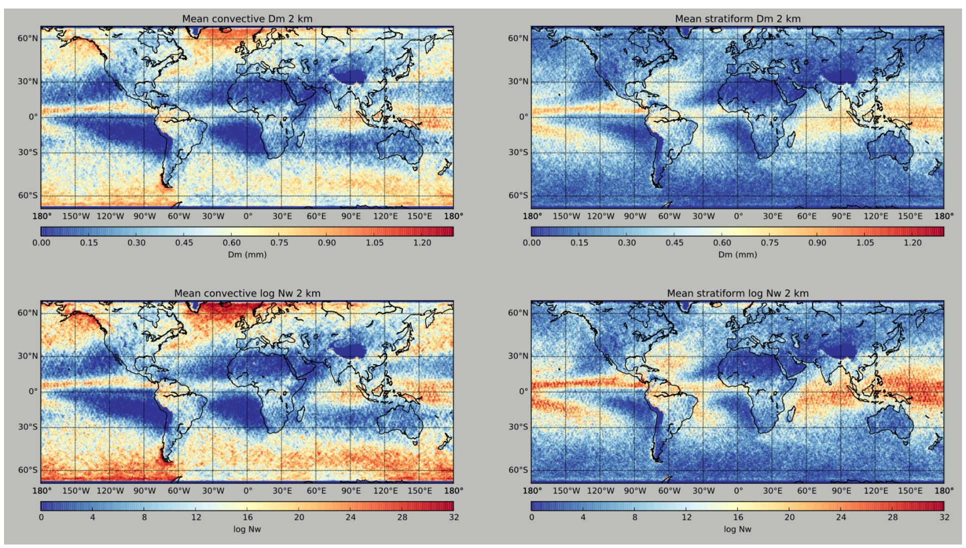
DPR retrieval assumptions

→Global column precipitation microphysical characteristics need to be captured for accurate retrievals

GPM DPR conditional mean D_m, N_w

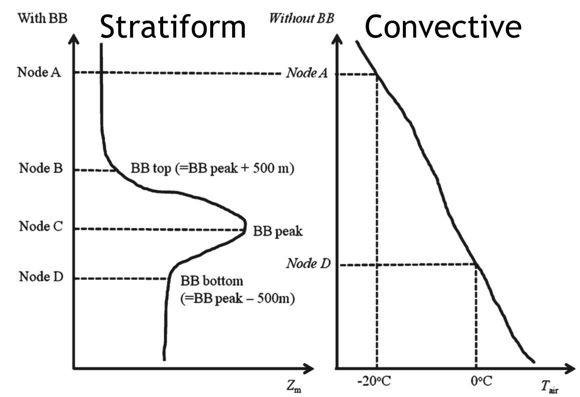


9 Mar 2014 – 30 June 2015

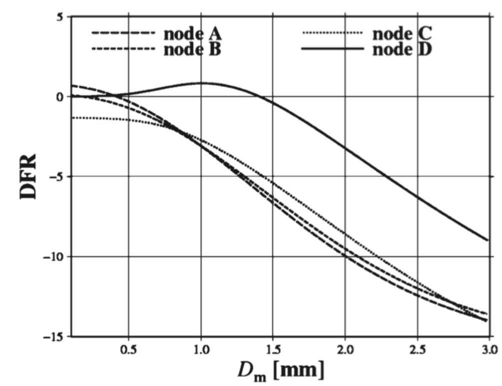
node	phase	T [°C]	P_w	P_i	ρ_s [g cm^{-3}]	U	α_0 for KuPR [x 10^{-4}]	β
node A	solid	-20	0.000	0.109	0.100	2.0	0.3124 [S] 0.4814 [C]	0.78069 [S] 0.75889 [C]
node B	melting	0	0.017	0.123	0.130	3.4	1.2651 [S]	
(between B and C)	melting	0	0.044	0.180	0.210	8.7	3.1409 [S]	
node C	melting	0	0.170	0.263	0.412	140	5.0167 [S]	
(between C and D)	melting	0	0.380	0.257	0.616	140	4.0639 [S]	
node D	liquid	0	1.000	0.000	1.000		3.1110 [S] 4.2864 [C]	

μ = 3

Hydrometeor particle size distributions, phase, and mass profiles



Scattering tables



Seto et al. (2013)

Challenges in ice and mixed phase precipitation

- Much of the in situ information about ice has been collected in particular regimes (orographic/anvil-stratiform)
  - lots of studies on clouds/light precipitation but less on precipitating ice and mixed phase clouds

- Ice properties important for precipitation and latent heating retrievals → improving models

- Synergistic approaches that combine in situ and remote sensing approaches key for moving forward
  - Large uncertainties, error characteristics in ice measurements difficult to obtain

GV algorithm issues in cold-season precipitation – Solid PSD Sub-Working Group

- Particle size distribution constraints in snow following Williams et al. 2014 (K. Harnos et al. 2015)
- Scattering properties in natural ice, mixed-phase particles
- Particle mass/density – Ice water content (IWC) – retrievals
- Fall speeds
- Mixed-phase processes, supercooled water, and riming

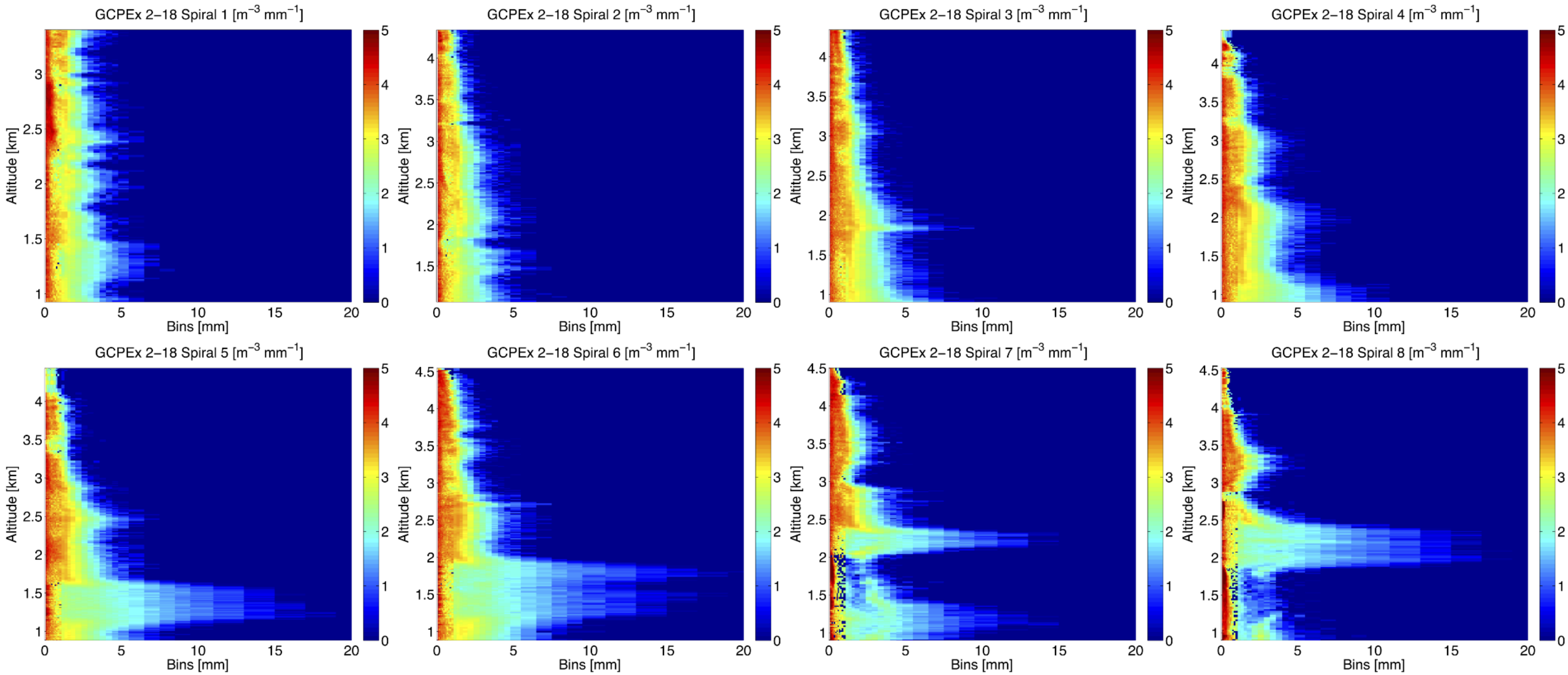
GCPEx – Jan/Feb 2012

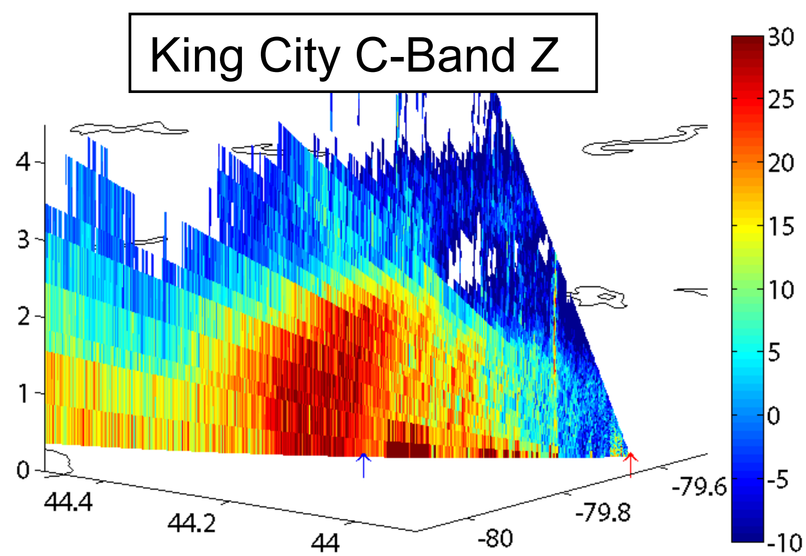
2DVD
Parsivel2
POSS
Hot Plate
Ref Gauges
...

EC King City C-Band
Dual-pol Doppler Radar
King City, Ontario

NASA/CSU D3R Ku-Ka Band
Dual-pol Doppler Radar
at the CARE Site

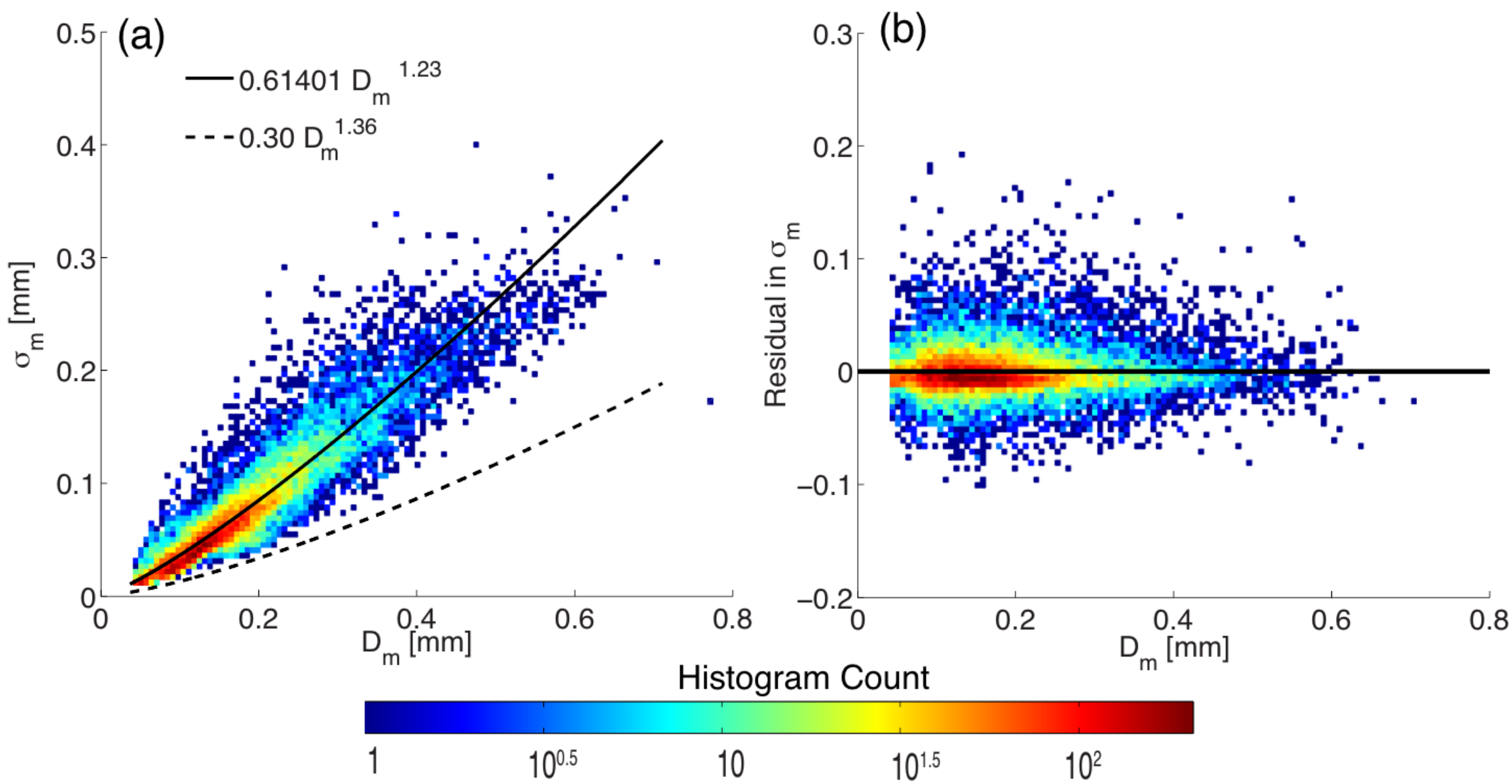
UND Citation





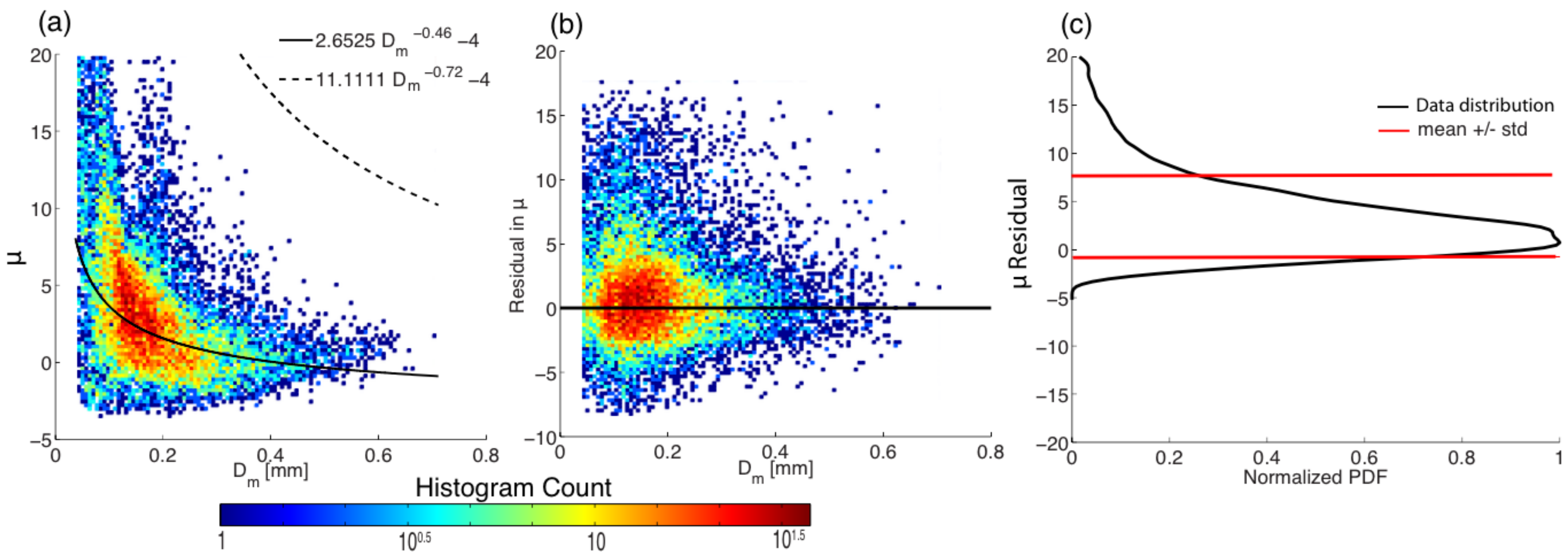
HPVS-3
CIP
2D-C

Sigma-m – Dm relationships from Citation GCPEX in situ data



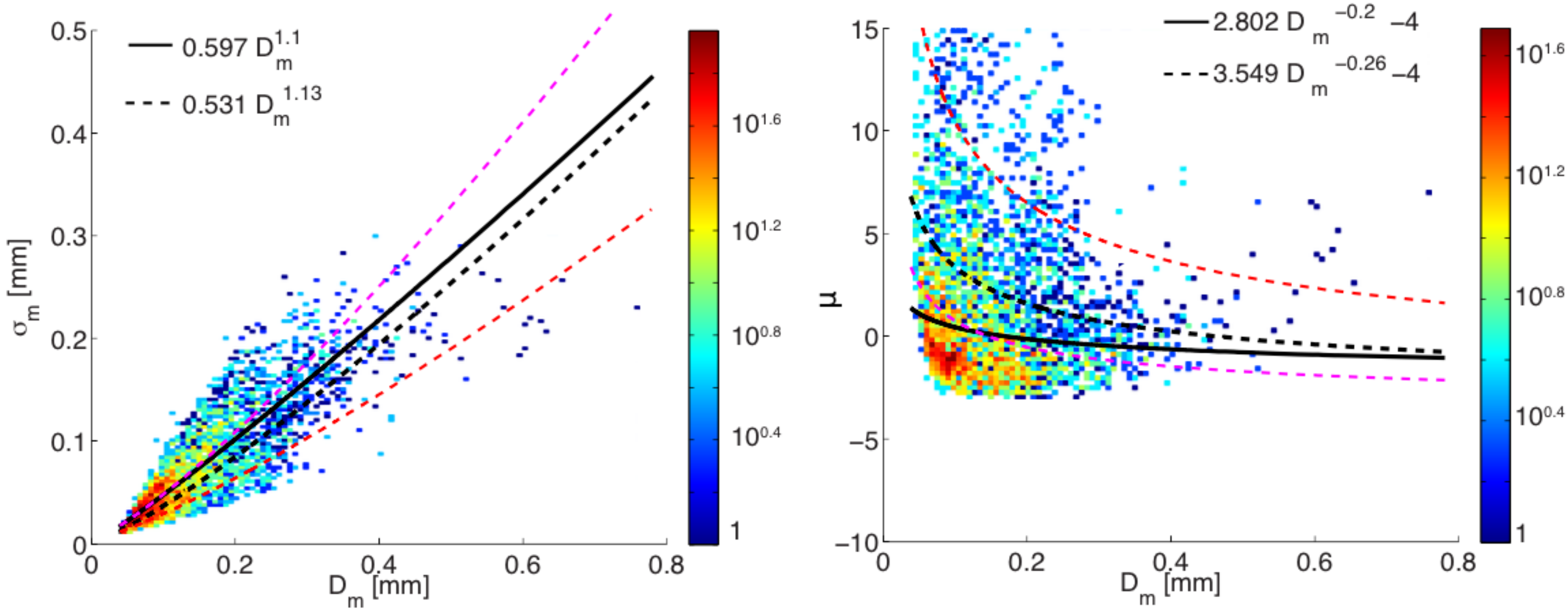
Solid line – Citation GCPEX data
Dashed line – Williams et al. (2014) rain data

Dm - μ relationships from Citation GCPEX in situ data



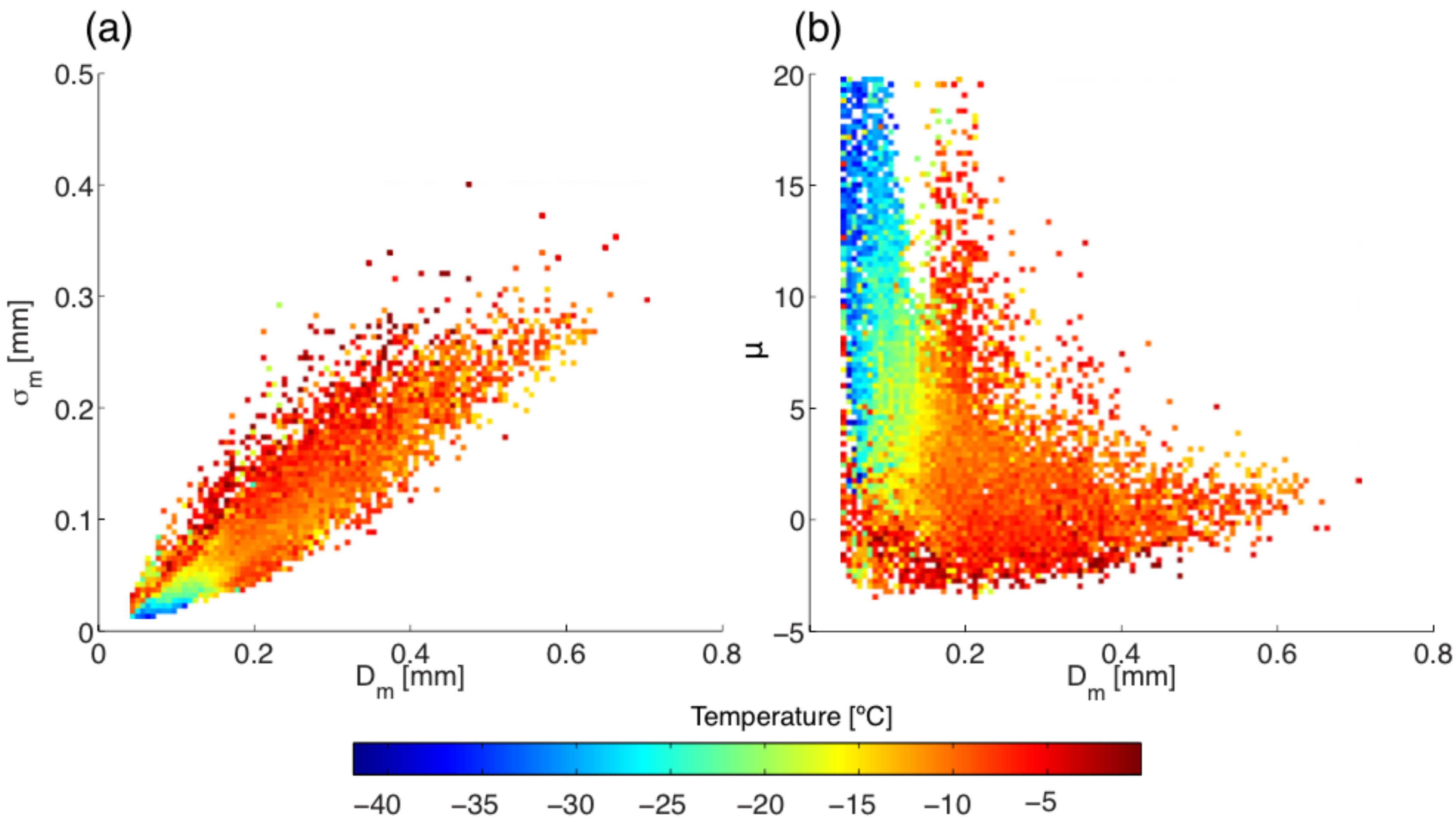
Solid line – Citation GCPEX data
Dashed line – Williams et al. (2014) rain data

Sigma-m - Dm and Dm - μ comparison with surface disdrometers

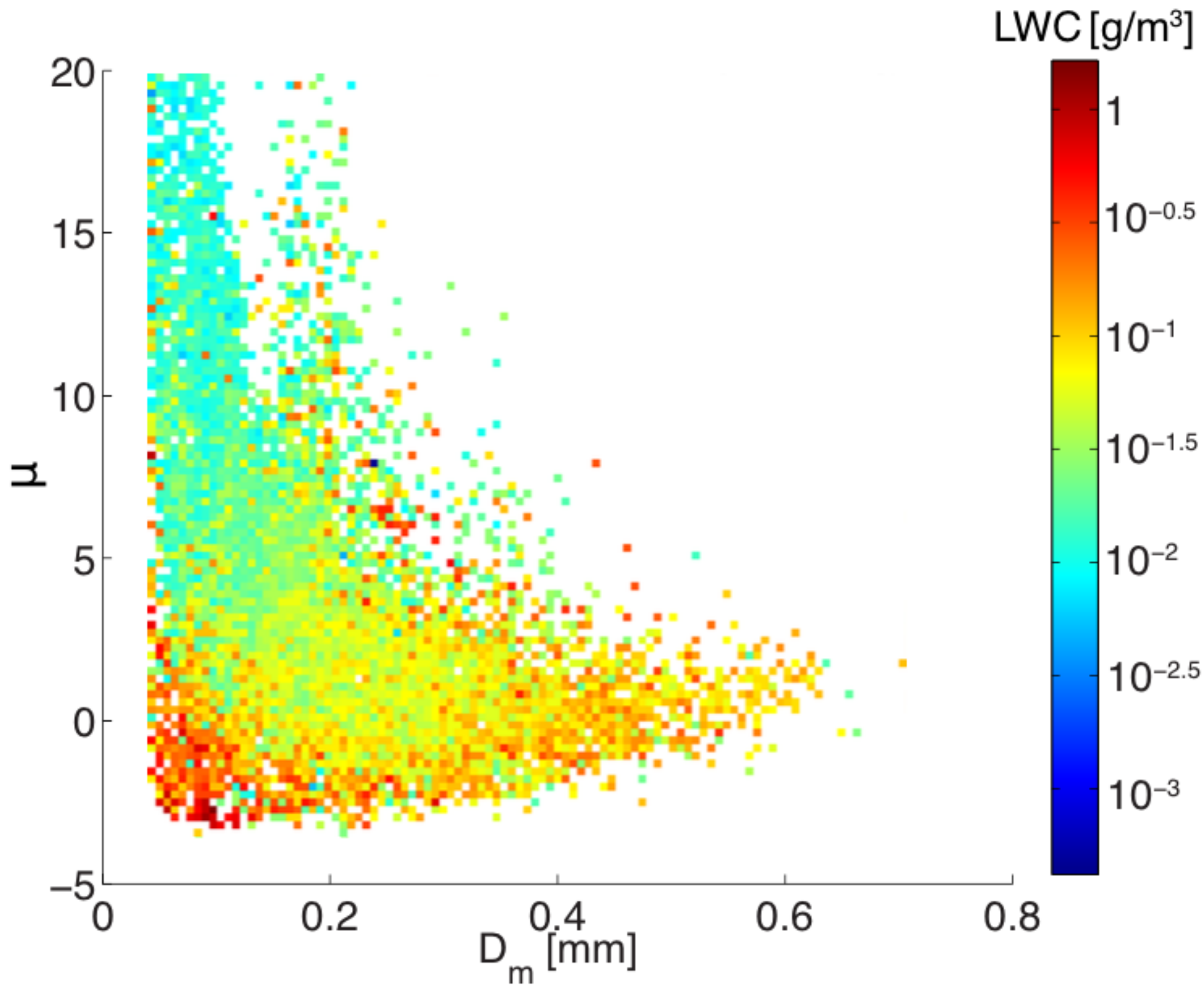


Solid line – 2DVD data from CARE site in GCPEX
Dashed lines – Citation GCPEX data +/- 1 standard deviation

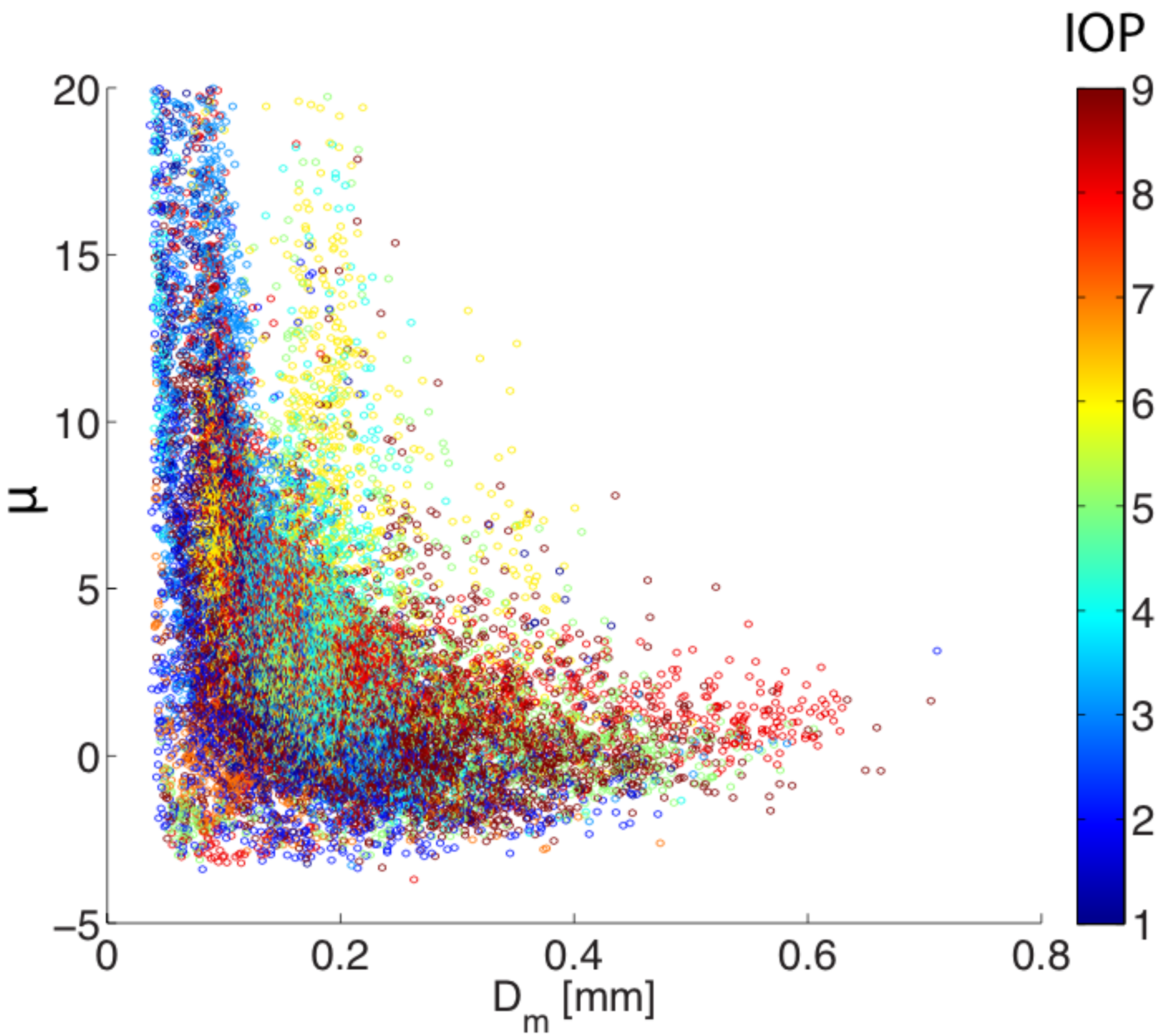
Investigating PSD relationships with environment: Temperature



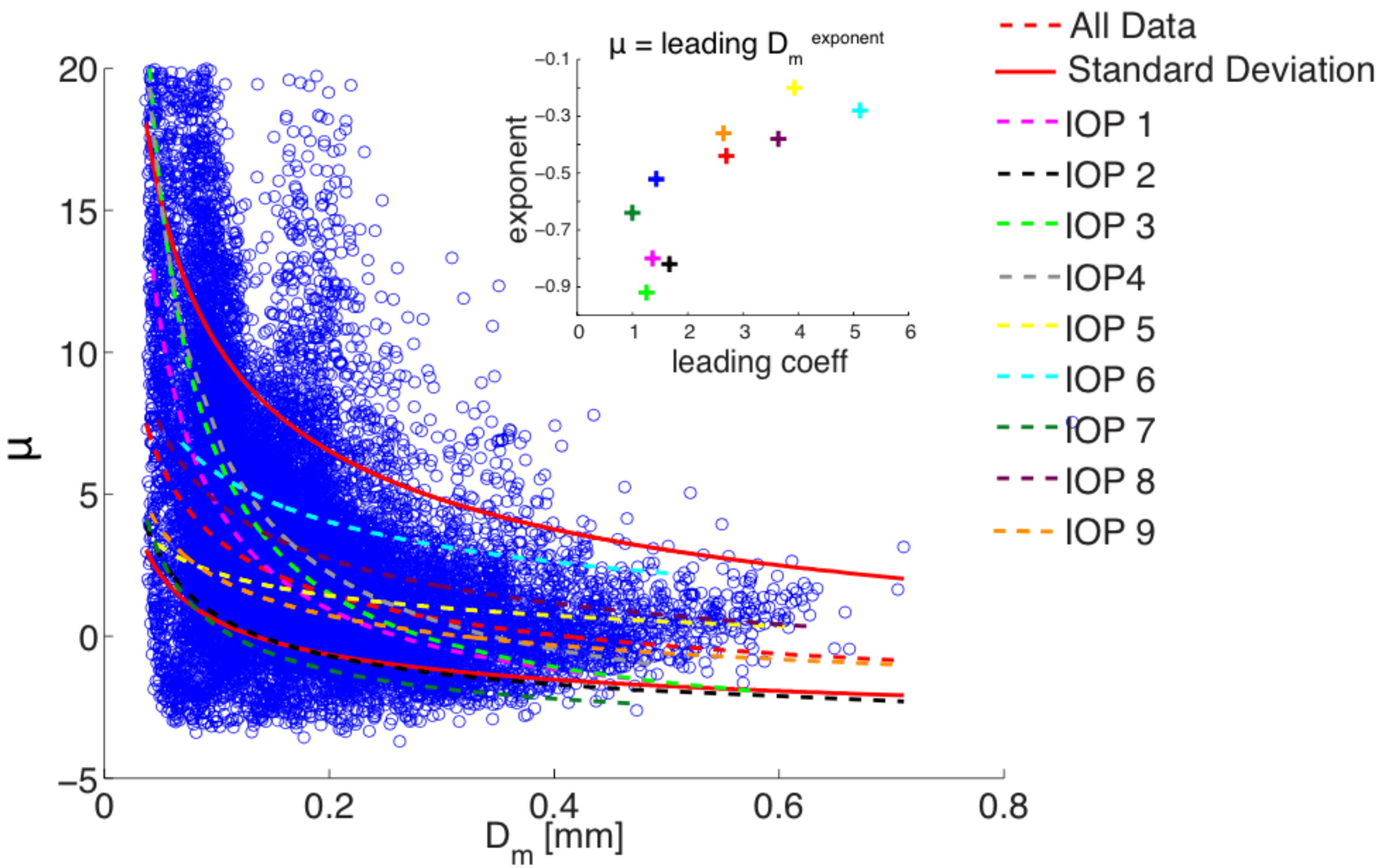
Investigating PSD relationships with environment: King Probe LWC



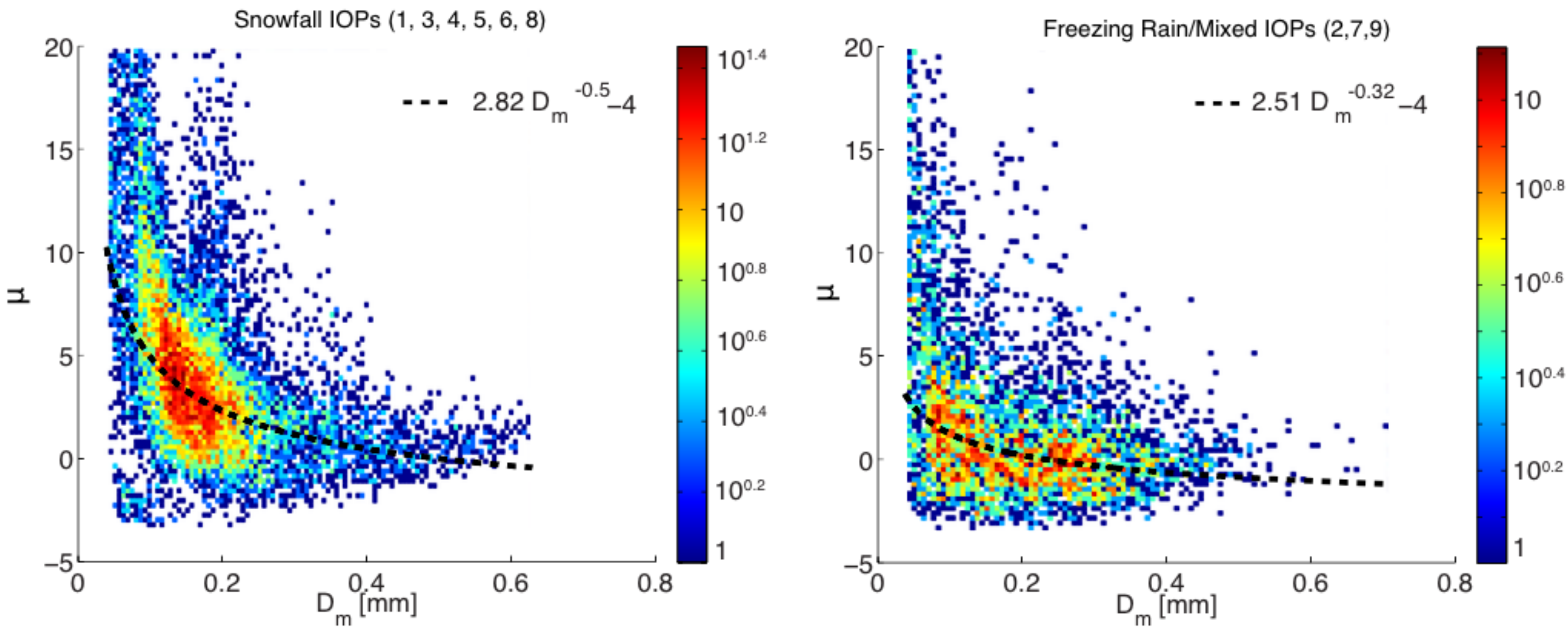
Investigating PSD relationships with environment: IOP variati



Investigating PSD relationships with environment: IOP variations



Sigma-m – Dm relationships for snow versus mixed-phase IOPs



Constraining mass-diameter assumptions

- Mass-Diameter (*m*–*D*) relationships are important unknowns in remote sensing retrievals and model microphysical parameterizations

- Many studies have attempted to quantify the *a* and *b* parameters in a form of

$m(D) = aD \uparrow b$

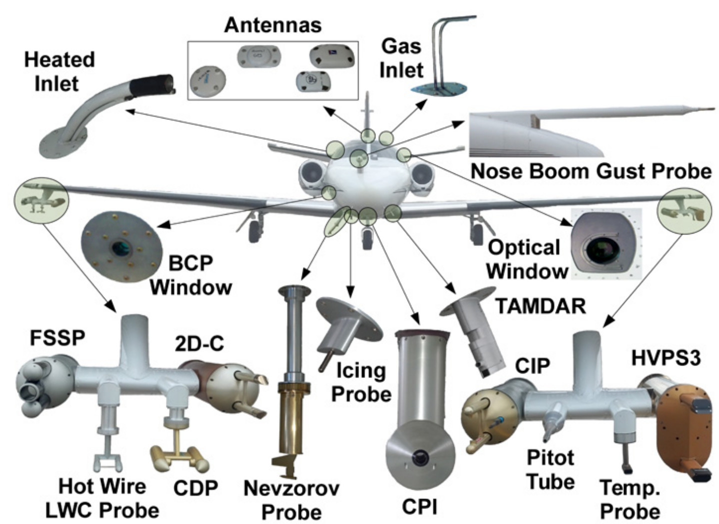
- The *a* and *b* have been quantified using total mass versus particle images, remote sensing consistency, and fractal dimension (FD)
  - Locatelli and Hobbs (1974): individual storms, orographic
  - Brown and Francis (1995): Hogan et al. (2012) noted that a=.121$D^{1.9}$ is consistent with Z_e
  - Schmidt and Heymsfield (2010): Argue that *b* should be 2-2.3 via FD
  - Heymsfield et al. (2010): Assess impact of FD *b* on determination of *a*
  - Hogan et al. (2012): noted that is BF consistent with $Z_{e,}$ but Heymsfield m-D predicts IWC but overpredicts Z

Goals and methodology

- Address consistency between Rayleigh Z – IWC – and m-D parameters using matched aircraft radar data in GCPEx

Data:

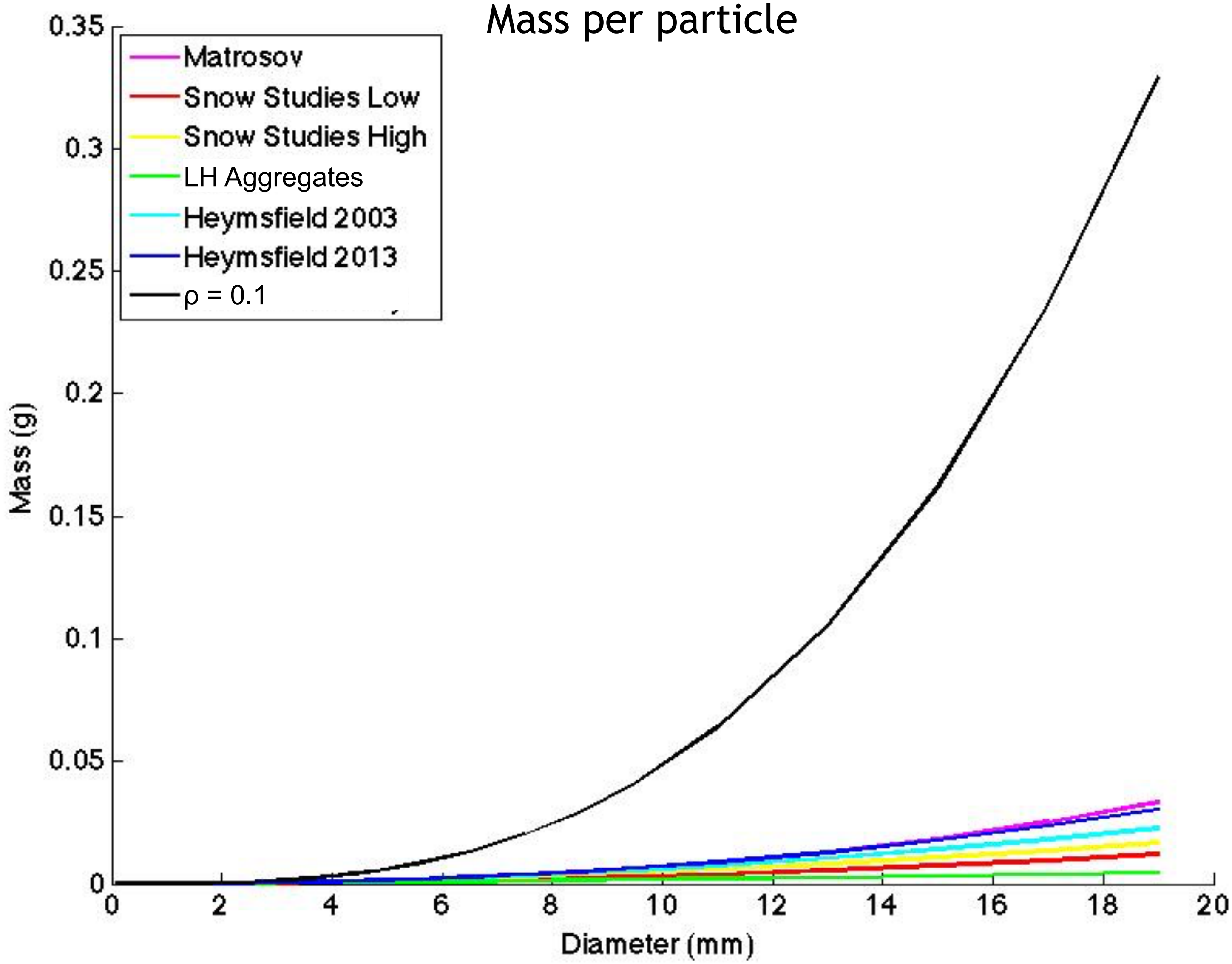
- Deep cone Nevzorov total water probe – total water content
  - How can we characterize the uncertainties?
- Cloud imaging probe + High Volume Precipitation Spectrometer-3
  - particle size distributions from 200 μm to 1.92 cm + reconstruction
- Environment Canada King City C-Band radar reflectivity
  - Advection estimated from Citation in situ winds, 1 m/s fall speed
  - ΔR_{max} = 250 m, Δt_{max} = 3 minutes
- 4 snow cases, King Probe LWC < .05 g/m^3



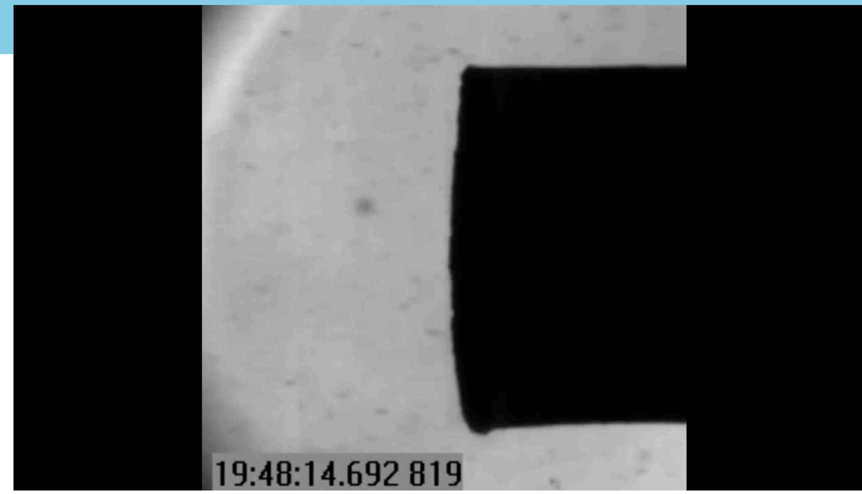
m-D relations in the literature

Author	m-D relationship ($D=D_{max}$ unless noted)	range
Matrosov 2007	$0.003D^{2}$	D < 0.2mm
Matrosov 2007	$0.0067D^{2.5}$	D > 0.2 mm
Szyrmer and Zwadadzki 2013	$0.0041D^{1.91}$	D > 0.2 mm
Szyrmer and Zwadadzki 2013	$0.0032D^{2.07}$	D > 0.2 mm
Szyrmer and Zwadadzki 2013	$0.005D^{1.87}$	D > 0.2 mm
Szyrmer and Zwadadzki 2013	$0.0032D^{1.85}$	D > 0.2 mm
Brown & Francis 1995	$0.0029D_{mean}^{1.9}$	general ice cloud particles, orographic
Locatelli & Hobbs 1964	$0.0018D^{1.4}$	Dendrites, Dendrite Aggregates (4-10mm)
Heymsfield et.al 2003	$0.0061D^{2.05}$	
Heymsfield et.al 2010	$0.004D^{2.1}$	
Heymsfield et.al 2013	$0.0081e^{0.013T}D^{(2.31 + 0.0054T)}$	
10% Ice Density (GPM DPR)	$0.048D^{3}$	

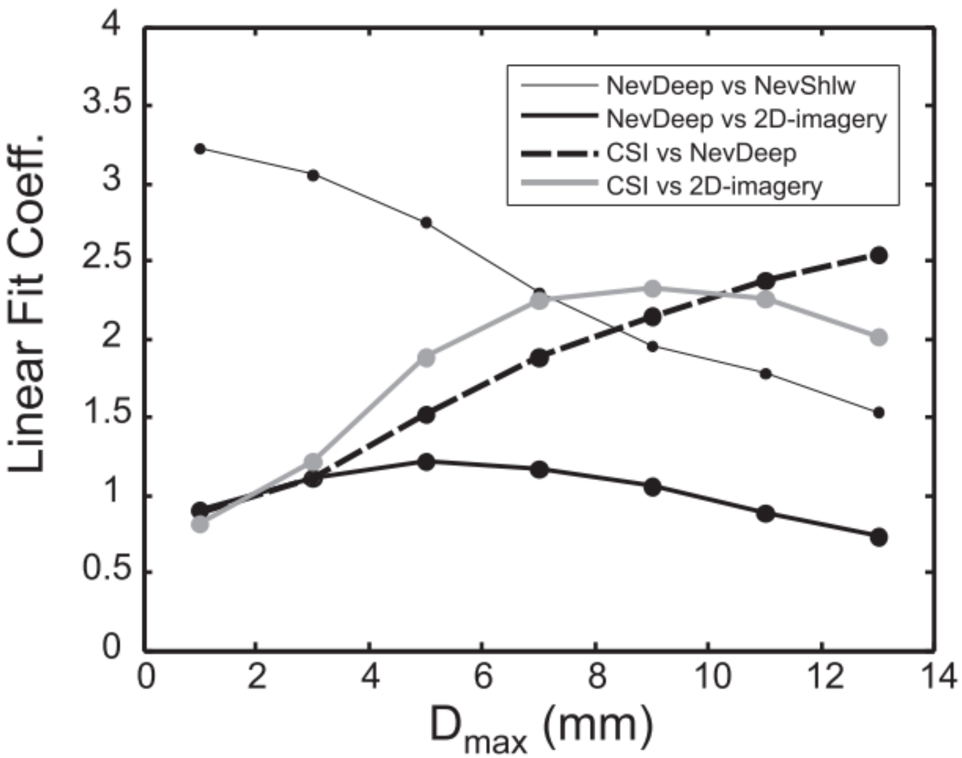
Mass per particle

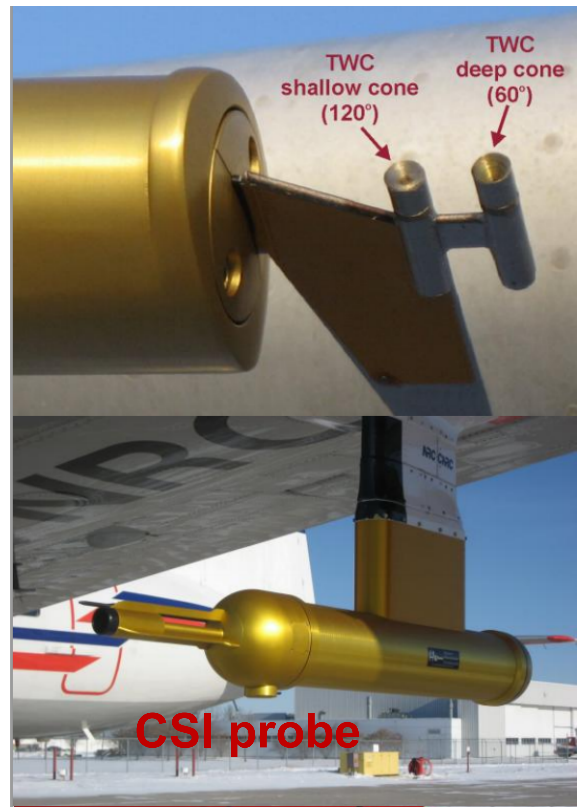


- IWC measurements can be problematic due to probe design



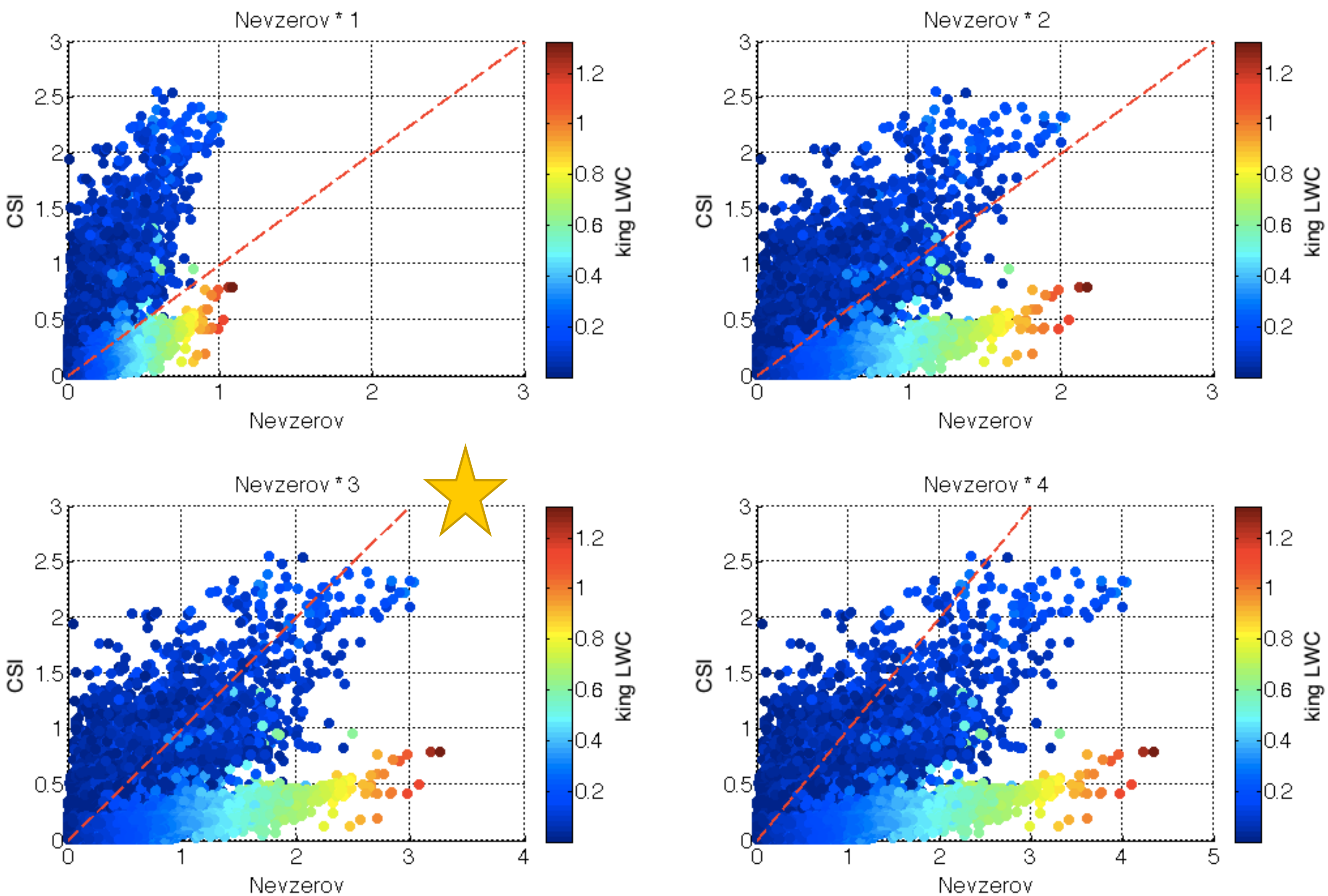
C3VP (2007) flew CSI + Nevzorov



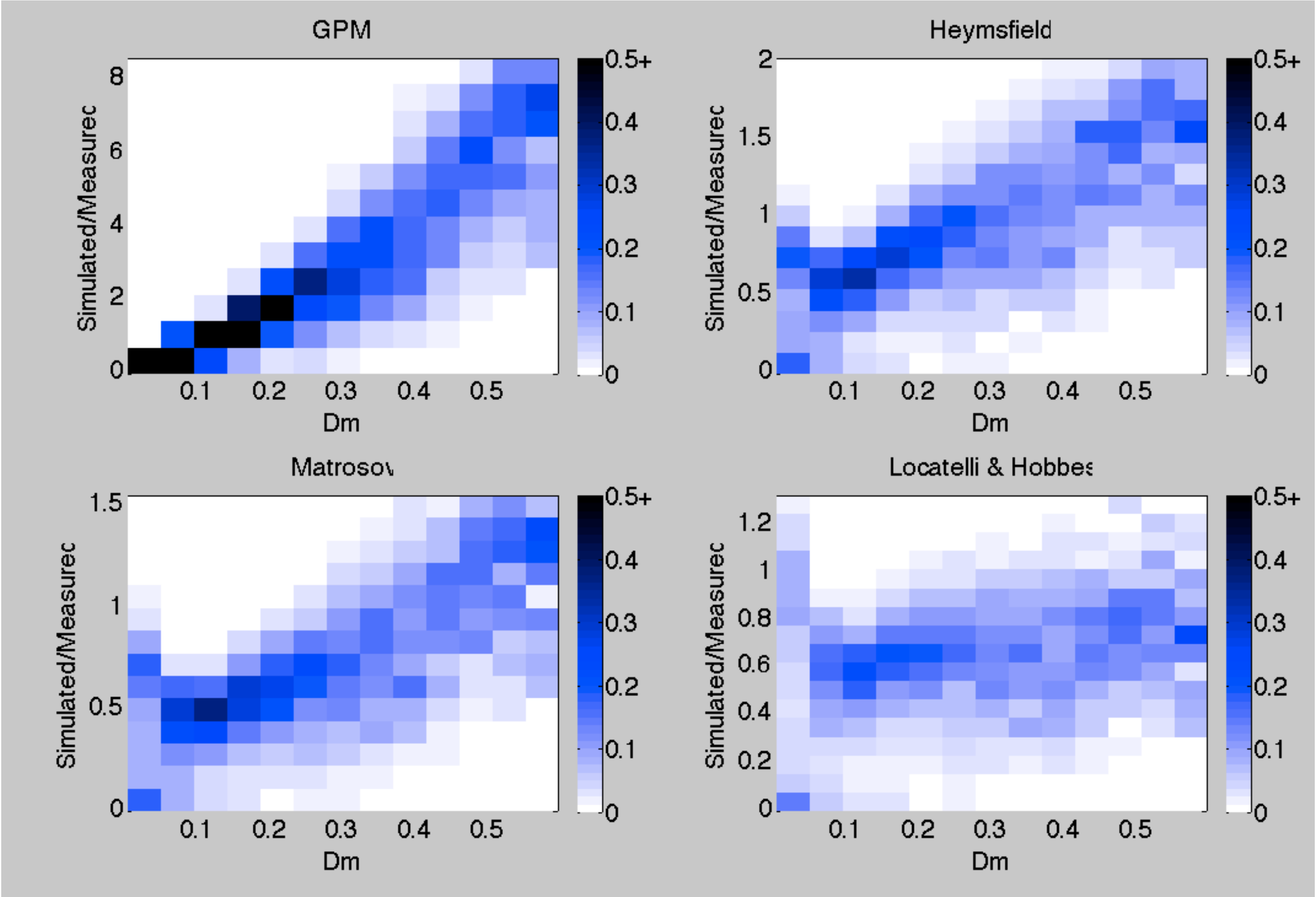


Korolev et al. (2013)

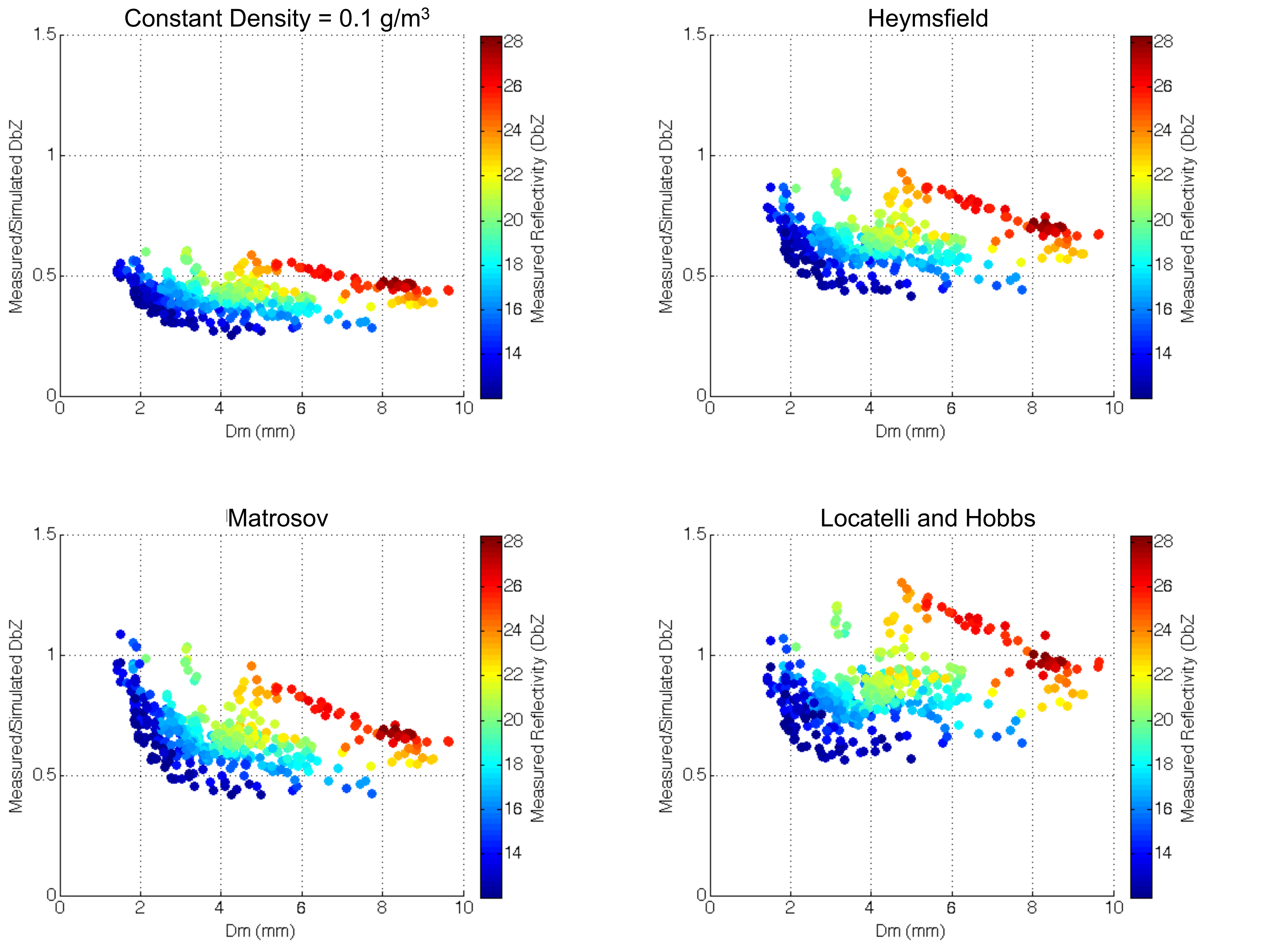
C3VP CSI vs Nevzorov IWC comparisons [g/m^3]



Simulated/Measured IWC
Modified Nevzerov



Dm (cm)


Constant Density = 0.1 g/m3
Heymsfield
Matrosov
Locatelli and Hobbs
Measured/Simulated DbZ
Dm (mm)
Measured Reflectivity (DbZ
0
0.5
1
1.5
0
2
4
6
8
10
14
16
18
20
22
24
26
28

mass-diameter $m(D)=aD^b$

number moment $$D_m = \int_{D_{\min}}^{D_{\max}} n(D) D^b \, dD$$

Z-weighted moment $$D_Z = \int_{D_{\min}}^{D_{\max}} n(D) D^{2b} \, dD$$

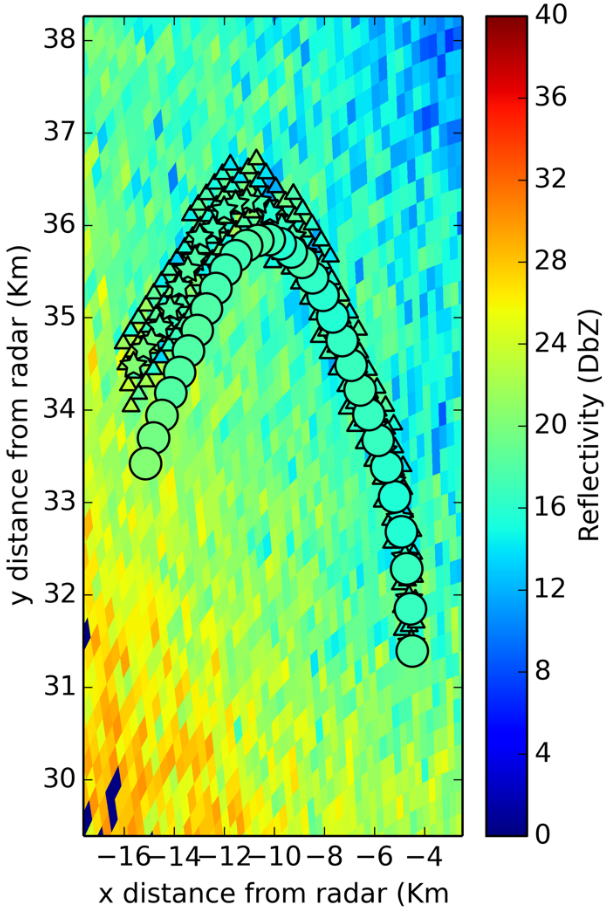
ice water content $$IWC = \int_{D_{\min}}^{D_{\max}} n(D) a D^b \, dD$$

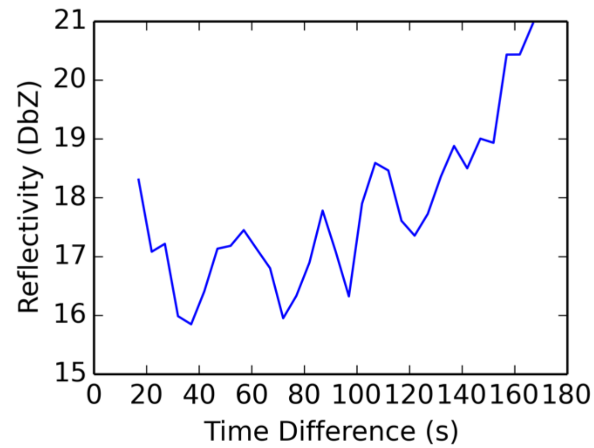
aIWC $$a_{IWC} = \frac{IWC}{D_m}$$

Rayleigh equivalent reflectivity factor $$Z_{eq} = \left(\frac{6}{\pi\rho_{ice}}\right)^2 \frac{|K_i|^2}{|K_w|^2} \int_{D_{\min}}^{D_{\max}} n(D) a^2 D^{2b} \, dD$$

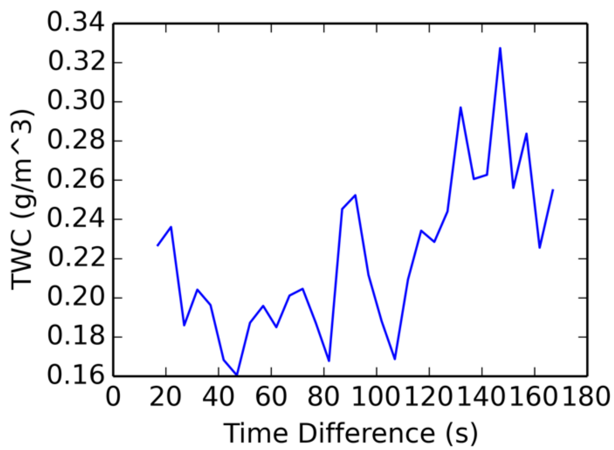
aZ $$a_Z = \frac{\pi\rho_{ice}}{6} \sqrt{\frac{|K_w|^2 Z}{|K_i|^2 D_z}}$$

Aircraft matching



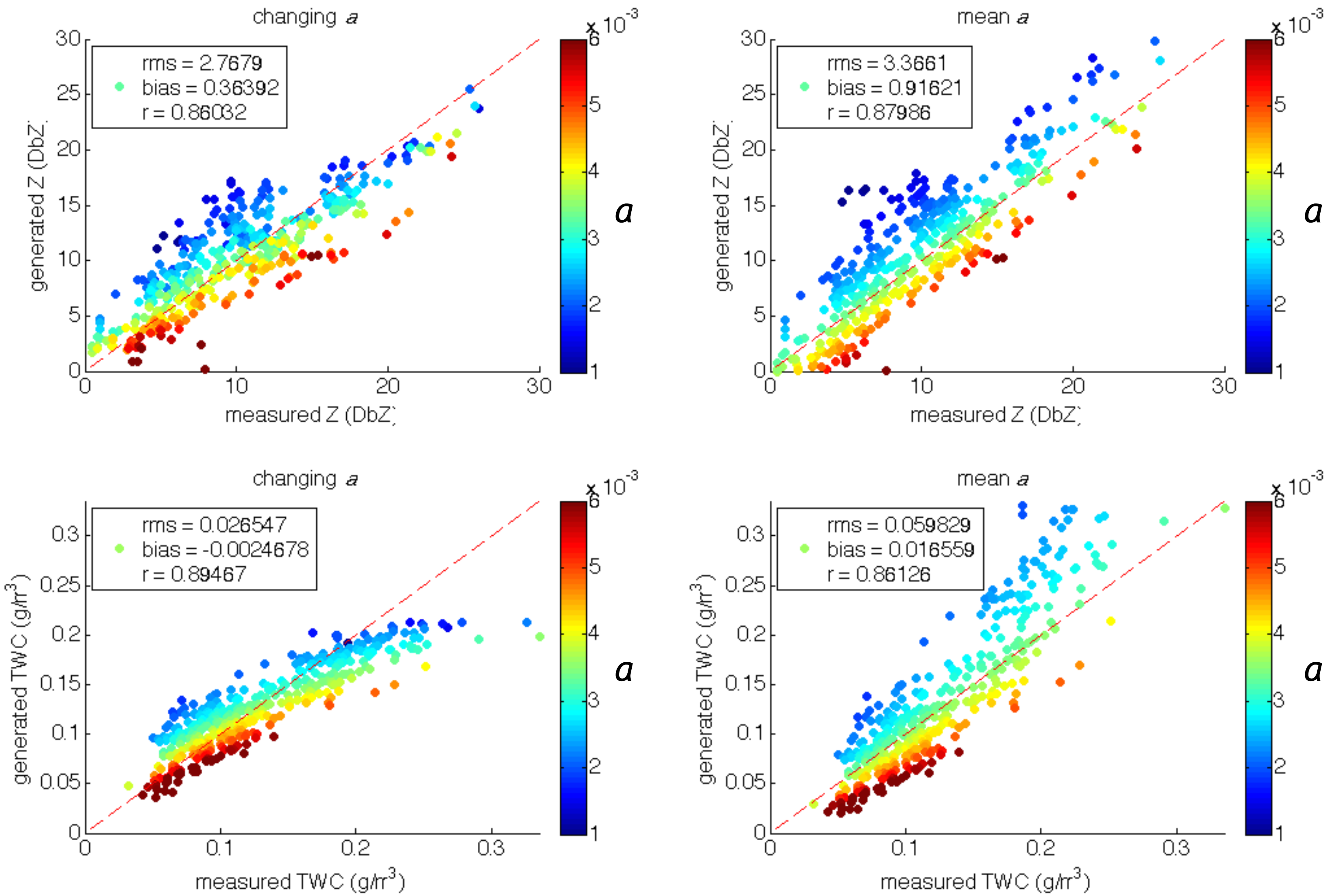


Advected C-Band reflectivity along flight track



Nevzorov total water content (g/m^3)

Fixed aD^b


changing a
rms = 2.7679
bias = 0.36392
r = 0.86032
generated Z (DbZ)
measured Z (DbZ)
x 10^-3
a
mean a
rms = 3.3661
bias = 0.91621
r = 0.87986
generated Z (DbZ)
measured Z (DbZ)
changing a
rms = 0.026547
bias = -0.0024678
r = 0.89467
generated TWC (g/m^3)
measured TWC (g/m^3)
mean a
rms = 0.059829
bias = 0.016559
r = 0.86126
generated TWC (g/m^3)
measured TWC (g/m^3)

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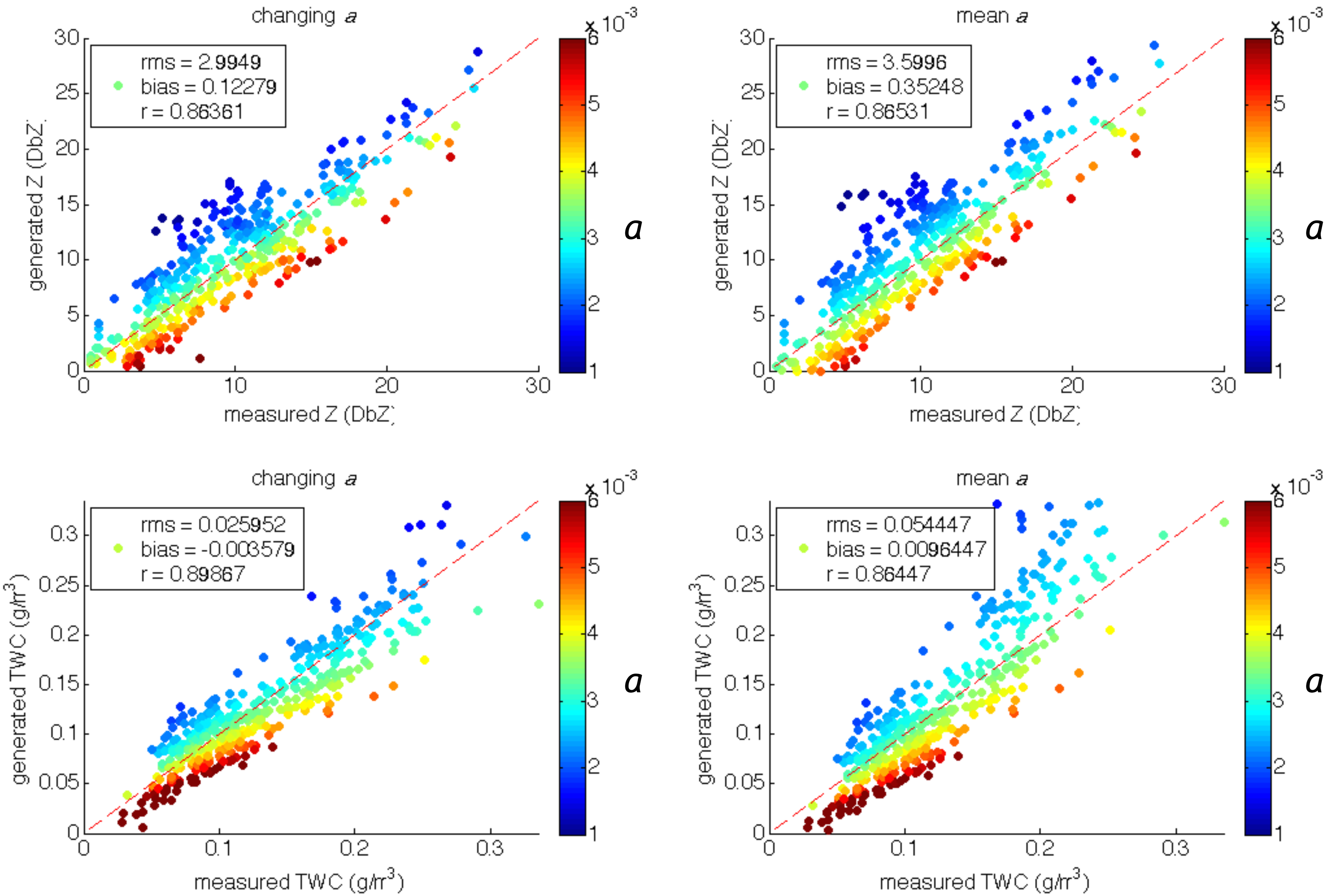
$a(Dm)D^b$



Conclusions

- Best consistency between Z-IWC and Z- achieved in GCPEx measurements when b=2.35 and a(Dm) is enabled
  - 1 dB error in Z_e calibration, *a* error proportional to $D^{0.5}$
  - Does this apply to other ice clouds?
  - Good IWC information critical for mass retreivals

Future work:

- Test with ground measurements?
- Relations to DFR (Dm), multi-wavelength, and dual polarization, incidence angle information
- Applicable to other sensors' retrievals, test with C3VP, IPHEx, and OLYMPEX data (CSI + Nevzorov)
- Examine mixed-phase conditions